Hydrogen Energy Systems as a Grid Management Tool

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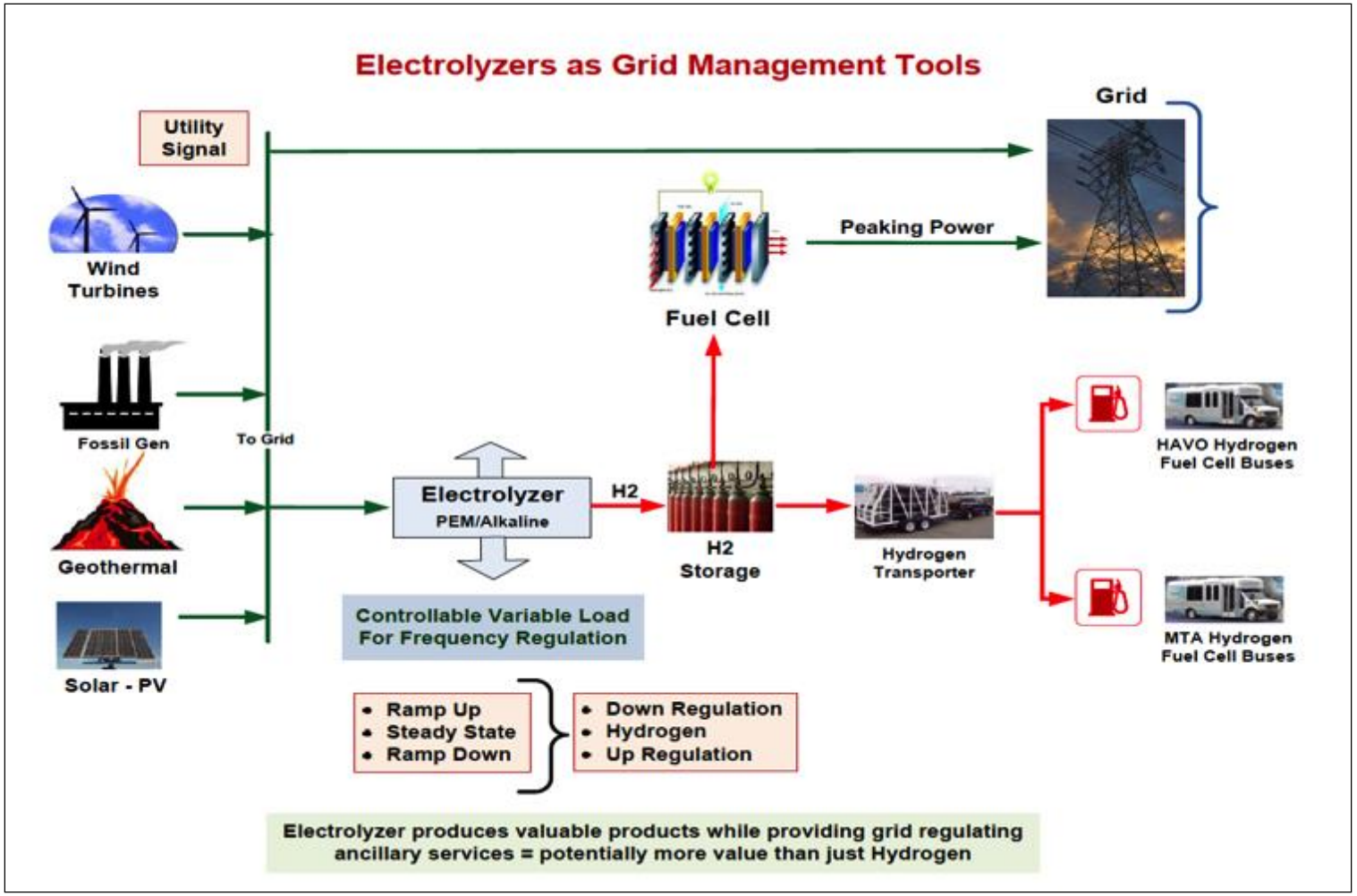
Grid Frequency Management

- ✓ **Electric power grids operate at a frequency of 60 Hz;**
- ✓ **Deviation from 60 Hz is a measure of the load balance of the grid – load matched to generation;**
- ✓ **With increased penetration of intermittent renewables on the grid the supply and grid frequency may be subject to fluctuations;**
- ✓ **Grid operators can stabilize the frequency by ramping power generation up/down or controlling variable loads or storage;**
- ✓ **Project Thesis: An electrolyzer can be used as a variable controllable load that can be reduced/increased in order to maintain the total load balance and frequency stability.**

Project Objectives

- ✓ **Validate the performance, durability & cost benefits of grid integrated hydrogen systems;**
  - ➢ **Demonstrate dynamic operation of electrolyzers to mitigate impacts of intermittent renewable energy;**
  - ➢ **Demonstrate potential of multiple revenue streams from monetization of ancillary services and producing hydrogen;**
  - ➢ **Supply hydrogen to shuttle buses operated by County of Hawaii Mass Transit Agency (MTA), and Hawaii Volcanoes National Park (HAVO);**
- ✓ **Support development of regulatory structure for permitting and installation of hydrogen systems in Hawaii.**

Concept



HNEI's concept to use an electrolyzer to provide grid ancillary services such as up-regulation, down-regulation, and off-peak load.

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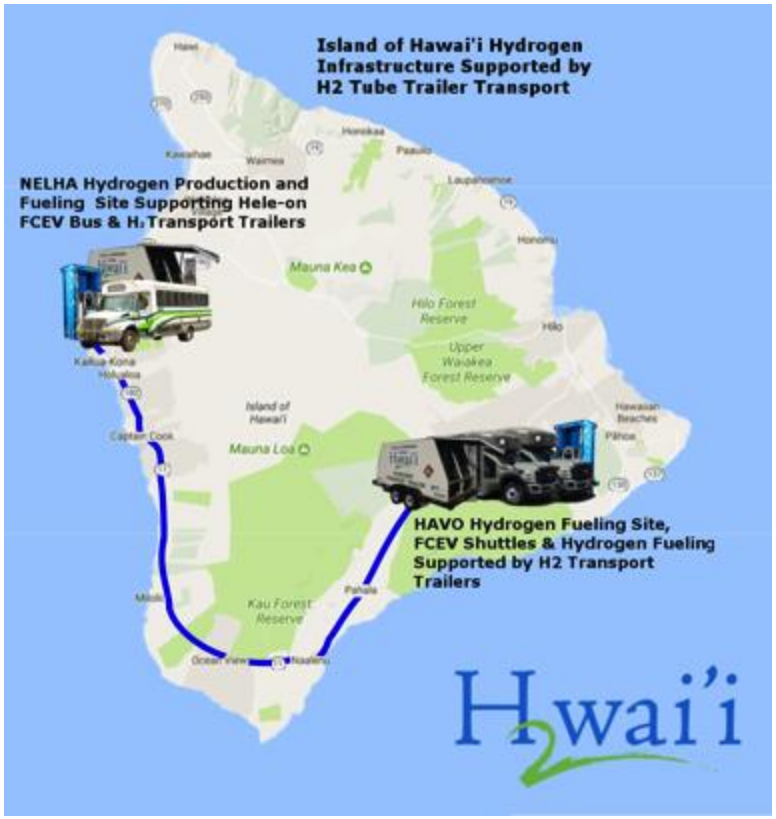
Central Site Production/Distributed Dispensing

Economically viable electrolytic hydrogen will require low cost electricity + high capital utilization.



- ✓ **Central site production for highest capital utilization;**
- ✓ **Distributed dispensing sites with minimum complexity to reduce fuel distribution costs;**
- ✓ **Optimize additional revenue streams from:**
  - ➢ **Quantify and monetize ancillary services;**
  - ➢ **Sale of hydrogen for transportation.**

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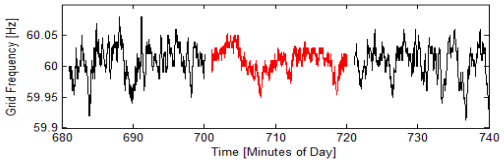
Use of Electrolyzer for Grid Ancillary Services



Grid Frequency (Hz): Measured with battery off (black) and on (red) at twenty (20) minute intervals

- **HNEI demonstrated ability to regulate grid frequency on 150MW grid with a fast-acting 1MW battery;**
- **Cycling tests suggest electrolyzer more appropriate for slower-acting changes;**
- **Battery/electrolyzer hybrid may provide grid services across broad range of operating conditions;**
- **Using electrolyzer as a variable load as opposed to battery allows effective use of CAPEX plus other value added services.**

Central Site Production Located at NELHA

- **State of Hawaii facility:**
  - **Strong political & financial support;**
  - **Significant cost share provider;**
  - **Leverages available technical staff.**
- **Ease of permitting;**
- **Existing infrastructure reduces site costs;**
- **Kona Airport offers opportunity to leverage project:**
  - **Airport ground handling equipment;**
  - **Airport shuttle buses;**
  - **Rental cars.**
- **Supports NELHA Vision of a "Hydrogen Hub";**
  - **Provides "enabling" infrastructure to attract new projects.**

NELHA Hydrogen Site Layout

Site Preparation

Excavation

Concrete Pad

Equipment Installation

Setting Equipment
20-ton Lift

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Site Work Completed

Site Work Completed

Tube Trailer Filling Bays

Dispenser

Converted 3 Fuel Cell Electric Hybrid Buses

County of Hawaii Bus (1) 29 Pass

HAVO Bus (2) 19 Pass

- **Hawaii MTA Fuel Cell Electric Hybrid Shuttle Buses demonstrate to the general public the advantages of fuel cell buses and electric drive.**
  - **Quiet ride;**
  - **No diesel fumes;**
  - **Potential for lower O&M costs (need low cost hydrogen).**
- **HAVO Buses will demonstrate HNEI's "Smart" air filtration sensor systems in a high air contaminant environment.***

(Funded by ONR).

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Recertified 3 Hydrogen Transport Trailers

- **Hydrogen Transport Trailer carries 105 kg @ 450 bar;**
- **Demonstrate distributed dispensing using cascade fill to 350 bar using a "Smart" dispenser;**
- **Trailer O&M costs will be evaluated including US DOT hydrostatic testing requirement every 5 years;**
  - **Currently no facility in Hawaii can hydro test cylinders of this size:**
  - **Must be shipped to mainland (very costly and time consuming);**
  - **Recertified Trailers before shipping to Hawaii to give us a full 5-year window.**

Collaborations

- ✓ **US Department of Energy: Project Sponsor & Funding;**
- ✓ **Naval Research Laboratory: Federal Technical Program Manager;**
- ✓ **Hawaii Natural Energy Institute: Implementing Partner, Technical Lead;**
- ✓ **Office of Naval Research: Supplemental Funding;**
- ✓ **State of Hawaii - HSDC: Public Outreach, Significant Cost Share;**
- ✓ **Natural Energy Laboratory Hawaii Authority: Host Site; Site Work, Cost Share**
- ✓ **County of Hawaii MTA: Host Site, Bus Operator (Cost Share);**
- ✓ **Hawaii Volcanoes National Park: Host Site, Bus Operator;**
- ✓ **HCATT: Conversion of Shuttle Bus, Cost share;**
- ✓ **US Hybrid: Conversion of Shuttle Bus, Cost share;**
- ✓ **HELCO: Interested Observer, Potential Partner for Grid Analysis;**
- ✓ **Hydrogen Safety Panel: Design Hydrogen Safety Review;**
- ✓ **PNNL: First Responder Training (Cost Share);**
- ✓ **Boyd Hydrogen: Site Hydrogen Safety Review, Permitting Department Workshop.**
- ✓ **Proton Onsite: Electrolyzer Control System**
- ✓ **Aloha Petroleum: Hydrogen Delivery**